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PROTECTION OF DRILL PIPE

IN ROTARY DRILLING AGAINST TWISTING

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From: Energeticheskiy Byulleten', [Power-Engineering Bulletin], No 9, September 1950, Moscow, Pages 26-28.

It is possible by means of an electro-rotor to obtain a sharp reduction in the torsional stresses which develops in the drill pipe used in rotary drilling. (A. A. Meshlumov "Improving the drive of the rotary table", Energeticheskiy Byulleten' (Power-Engineering Bulletin) No 9, 1949).

The electro-rotor eliminates the complex mechanism of transmission from the electric motors to the rotary table, thereby reducing the moment of gyration of the drive and increasing its efficiency.

Being an electrified machine, fully suited to the needs of technical policy in the field of electric drive of industrial machines, the electro-rotor can be readily automatized and used, for example, for its automatic change over from the motor to the generator function thereby protecting the drill pipe from twisting.

When an electro-rotor changes over from its motor to its generator function, it stops turning the drill pipe and automatically becomes a machine which relieves the drill pipe from becoming twisted by the kinetic energy of the rotating masses. Particular significance must be given the electro-rotor in the high-speed drilling of wells, wherein present-day rotary table speeds reach up to 500 revolutions per minute. The effectiveness of one of the valuable properties of the electro-rotor -- the automatic relief of the drill pipe from twisting when the bit is

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wedged -- depends on the electric parameters of the electro rotor. If one were to visualize the rotating mass of the electro-rotor and of the drill pipe as a kinetic energy condenser, then the efficiency of the regenerative braking effect of the electro-rotor can be determined by comparing the mean discharge capacity being regenerated into the power network with the charging capacity of the electro-rotor when functioning as a generator.

To determine the mean discharge capacity that can be regenerated into the electric power network, we can utilize the equation of energy balance in regenerative braking.

In doing this, since the basic cause of twisting of the drill pipe when the bit is wedged is due to the rotating mass of equipment above ground, we shall simplify the problem by examining the regenerative braking of only one electro-rotor without considering its connection with the drill pipe.

For the assumed condition

$$A_{regen} = -[A_1 - A_2] =$$

$$= -\frac{GD^2(n_1^2 - n_2^2)}{729{,}000} \text{ Kw/sec}, \qquad (1)$$

where A_{regen} is the energy which can be regenerated into the network;

$A_1 = \frac{GD^2 n_1^2}{729000}$ = the kinetic energy of the rotating masses of the electro-rotor at the begining of braking; and

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$A_2 = \frac{GD^2 n_2^2}{729,000}$ - the same at the end of the regenerative braking.

Examining the process of regenerative braking of the electro-rotor in the interval of revolutions from n_1 to the final speed n_2, the differential equation of the motion of the electro-rotor functioning as a generator can be given as

$$M_{gem} = -\frac{GD^2}{375} n_2 \frac{ds}{dt}, \qquad (2)$$

where s is the slip of the electro-rotor.

Utilizing the Kloss equation, equation (2) can be represented as

$$M_{gem} = \frac{M_{gyr.gem}(2+2\Sigma)}{\frac{s}{s_m} + \frac{s_m}{s} - 2\Sigma} =$$

$$= -\frac{GD^2}{375} n_2 \frac{ds}{dt}.$$

From which, after transforming and integrating we obtain

$$t = \frac{1}{2(1+\Sigma)} \cdot \frac{GD_2 m_2 s_m}{375 M_{m\,gyr.\,gen}} \times$$

$$\times \left[\frac{s^2_{initial} - s^2_{final}}{2 s_m} + \ln \frac{s_{initial}}{s_{final}} - \right.$$

$$\left. - \frac{2\Sigma}{s_m} (s_{initial} - s_{final}) \right]. \qquad (3)$$

Since $A_{regen} = P_{mid} \cdot t$, substituting the values for A_{regen} and t we obtain

$$P_{mid} = \frac{GD^2(m_1^2 - m_2^2)}{729{,}000} \text{ kw.} \qquad (4)$$

For the design parameters of the electro-rotor, the values ε and $M_{gyr.\,gen}$, after time t has been determined, can be found from the expressions:

$$\Sigma = \frac{R_1}{\sqrt{R_1^2 + X_K^2}} \qquad \text{and}$$

$$\frac{M_{gyr.gem}}{M_{gyr.\,motor}} = \frac{R_1 + \sqrt{R_1^2 + X_K^2}}{R_1 - \sqrt{R_1^2 + X_K^2}}$$

where $X_K = X_1 + X_2'$ is the

[redacted] full reactive resistance at short circuit of the electro-rotor; and

R_1 the active resistance of the stator winding at the braking stage.

Substituting in expression (3) the given data of a design variant of a 4-speed electro-rotor with synchronous speeds of 500, 374, 250, and 125 revolutions per minute, with a moment of gyration GD^2 = 2500 kilogram-meter, we obtain

$$t = 1.7 \text{ seconds}$$

From which P_{mid} from equation (4) will equal

$$P_{mid} = \frac{2500\,(450^2 - 125^2)}{729000 \times 1.7} = 390 \text{ Kw.}$$

Figure 1 shows the curves of the moments $M = f(s)$ for the electro-rotor with the highest step of speed n = 500 rpm and the braking step n_2 = 125 rpm.

When the regenerative-braking time was determined, it was assumed that the slip of the electro-rotor at the moment of its change-over from motor to generator was $s' = 0.1$. In this case the electro-rotor passing automatically from point a into point b, changes its slip in the generator connection, in the process of regenerative braking, from the initial value $s_{initial} = -2.6$ to the final value $s_{final} = -0.05$ at the end of braking (region of curve b - c - d).

The power that the electro-rotor can charge into the generator (with s_m at the minimum number of revolutionsin the motor equal 0.43), is determined from the expression

$$P_{gyr.gem} = \frac{M_{gyr.gem} \cdot n_2 [1-(-0.43)]}{975} =$$

$$= \frac{2160 \cdot 125 \cdot 1.43}{975} = 400 \text{ KW.}$$

Comparing the mean discharge capacity of the energy which can be regenerated into the network with the braking power which the generator can charge, we can conclude that with the given electric parameters and the moment of gyration of the electro-rotor, the latter is fully capable of regenerating into the power network all the kinetic energy of the rotating masses within the limits of numbers of revolutions between $n_2 = 500 - (500 \times 0.1) = 450$ rpm to 125 rpm. Thus, after returning most of the kinetic energy of the rotating masses into the network, and after reconnecting the electro-rotor into the motor mode of operation with the minimum number of revolutions, further protection of the drill pipe against twisting (should the wedging of the bit continue) will continue automatically through the lowered speed of the electro-rotor (region d - e) of the curve. In connection with this, the maximum power which the electro-rotor can develop and charge into the line when it is changed-over into the motor function with minimum number of revolutions, as computations show, can represent at best only 50% of the nominal rating of the electro-rotor, operating up to the transition into regenerative braking at the highest speed step, n = 500 rpm.

The described method of protecting drill pipe against twisting (author's certificate No 80613) introduces also new possibilities in the automatizing of the rotary drilling method, which automatization has up to now not received due solution to its problem.

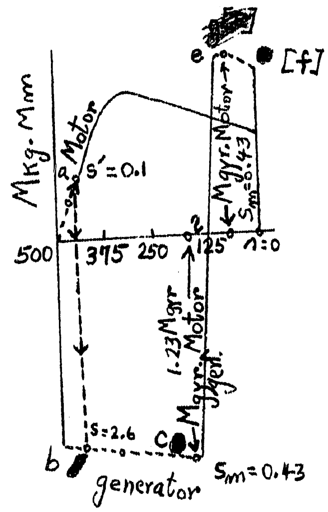

Figure 1

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